The Ohio State University

Department of Geology

Baselevel Sedimentation, Flint Ridge, Kentucky

A thesis in

Geology

by

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and

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Introduction.

Our object in this report is to examine and describe near-baselevel sediments in an active cave system and to determine the feasibility of further study of sediments in this cave. Cores were taken at 300 foot intervals along the cave passage. These cores were taken from Columbian Avenue, in the Flint Ridge Cave System, Mammoth Cave National Park, and were described in detail, with emphasis on the physical characteristics, for the purpose of establishing criteria for correlation within the cave fills.

Geology

Rocks exposed in the cave area are of the Mississippian and Lower Pennsylvanian Systems. The general stratigraphic section presented here was prepared by Dr. E.R. Pohl(personal communication) and is representative for the Central Kentucky Karst including Mammoth Cave National Park.

STRATIGRAPHY

Pennsylvanian System

Caseyville Formation. Sandstone and conglomerate; minor amount of shale and coal, typically tan, thick bedded, and soft. Occurs as fills in channels cut as much as 350 feet into underlying beds.

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Mississippian System

Leitchfield Formation. Shale with minor amount of limestone, maximum thickness of 140 feet, dark grey to black. Forms a covered interval on the outward slope of the Pottsville Escarpment.

Glen Dean Limestone. Limestone, dark blue-grey, with thin fossiliferous shales, grading into Leitchfield above, 45 to 75 feet thick.

Hardinsburg Sandstone. Sandstone, soft, blocky, thick bedded, tan, 30 to 70 feet thick.

Golconda Formation.

Haney Limestone Member. Limestone, medium grey, dense, crinoidal, cherty, thin to thick bedded, 20 to 45 feet thick.

Big Clifty Sandstone Member. (Cypress Formation of older literature). Sandstone or shale, variable both laterally and vertically, sandstone is crossbedded and yellowish, shale is micaceous, interbedded limestone lenses, coal and pyrite-bearing black shale common at top. The caprock of the most cavernous limestones; lowest formation cut through by Caseyville channels, 50 to 70 feet thick.

Beech Creek Limestone Member. Limestone, dense; and calcareous shale, 2 to 10 feet thick.

Elwren Mudstone Member. Shale, blue-grey, partly calcareous, dense, thick bedded, 0 to 15 feet thick.

Girkin Formation. (U.S.G.S. name) Limestone, light to dark grey, some yellow, mostly thick bedded, some oolites, some dolomitization, upper limestone "varved" in most places, some platy chert, minor quartz sand, 63 to 137 feet thick.

St. Genevieve Limestone. (U.S.G.S. name) Limestone, light gray, fine grained to conglomeratic, some oolites, some dolomiteization prominent, chert concretions and nodules, fluorite in vugs, some fossiliferous beds, 115 to 155 feet thick. Differentiable into several members.

St. Louis Limestone. Limestone, dark gray, abundant chert nodules to within 5 feet of St. Genevieve, dense to coarsely crystalline, laminated and shaley or silty in lower 50 to 100 feet. 250 to 350 feet thick.

Salem and Warsaw Limestones. Limestone and siltstone, gray to dark gray, varied lithologies, mainly fossiliferous limestone and dolomitic siltstone. 70 to 130 feet thick.

Fort Payne Formation. Dolomite, gray, silty, +140 feet thick.

These rocks dip approximately 30 feet per mile to the northwest. They are part of a karst belt that extends along the entire western flank of the Cincinnati Arch from southern Indiana south and east to Tennessee. The karst area of this study is developed in the thick St. Louis--St. Genevieve--Girkin limestone sequence.

The study area, Flint Ridge, is held up by the capping Big Clifty sandstone with interbedded layers of impermeable shale. Karst development was initiated by the breaching of this caprock by the Green River.

The Mammoth Cave Plateau region is structurally very simple. It is located in a broad synclinal trough bordering the Cincinnati Arch. West of Flint Ridge, a group of normal faults striking N60°E have been mapped (Deike,1967). Several minor normal faults have been described in the study area. One, striking N 20°W, crosses the Green River about three miles east of the Flint Ridge Cave System. Its displacement varies from 40 to 60 feet near the river. Joints in the karst area are irregular and poorly developed. Gentle folds whose axes trend northwest are common to Flint Ridge.

Physiography.

The study area is approximately midway between Louisville, Ky., and Nashville, Tenn., in West-Central Kentucky at Latitude $37^{o}12'45"$N, Longitude $86^{o}03'40"$W.

The Flint Ridge Cave System is beneath the Mammoth Cave Plateau, which is a broken upland at 740 to 860 feet in elevation. Remnant portions of the upland form mesa like "ridges", one to two miles wide and five to eight miles long with surfaces sloping gently west. Flint Ridge is bounded by the Green River to the north and west and by Mammoth Cave Ridge to the southwest. Beneath these two ridges are the two longest cave systems on the North American continent (Watson, 1966).

Mammoth Cave National Park encloses parts of the Mammoth Cave Plateau and the Hilly Country physiographic provinces of the Central Kentucky Karst., To the south is the Pennyroyal Plain, a rolling, sinkhole-studded plain, at 720 to 770 feet in elevation, Most of the sinkholes are20 to 60 feet deep, as much as 80 feet in diameter, and most of them have gentle, smoothly sloping sides. In contrast, the sinkholes bounding the ridges of the Mammoth Cave Plateau to the north are mostly much deeper and have steeper sides. The Dripping Springs Escarpment forms the southern boundary of the Mammoth Cave Plateau, whereas the northern border, north of the Green River is formed by the Pottsville Escarpment (Davies, 1959).

The average annual rainfall for the region is 47 inches, with about 10 inches of snowfall annually. The spring thaw with accompanying high water occurs from late January through March. Mean annual temperature is 58^{o}F and the Plateau is covered with a temperate deciduous forest of oak, hickory, and southern hardwoods typical of the Interior Low Plateaus.(Watson, 1966).

The Green River has cut a narrow deep valley across the Mammoth Cave Plateau. It is the controlling base level stream of most of the karst region. Irregular ingrown meanders with a sinuosity of about 1.75 are present. Erosion remnants are rare in the river valley. The present flood plain lies at 450 feet; the river at about 420 feet, and there is a bedrock channel at about 390 feet elevation (Deike, 1967). Davies (1959) reports terraces at an elevation of 460 to 470 feet along the Green River in Mammoth Cave National Park. Haynes (1966) mapped "older" alluvium at 600 to 620 feet on the inside of river bends six to nine miles east of Mammoth Cave.

Hydrology.

Smith (1961) reports that the mean annual discharge for the Green River at Mammoth Cave is 2882 cfs (for twelve years on record). The mean monthly discharge varied from 271 cfs in October to 7127 cfs in February. Flood rises of five to ten feet occur, mostly dependent on storms. Flow-duration curves show that the Green River flows in excess of its mean annual discharge about 28% of the time. Water at or above the mean discharge rate occurs from January through April. Except for September and October, when low water is reached, the river averages 1.4 feet above low water (Cushman and others, 1965).

Almost all the streams in the area are dry during the summer. Exceptions are small spring-fed streams on the Mammoth Cave Plateau, and streams with a discharge of up to 5 cfs in the Cub Run area north of Green River (Deike, 1967).

Large springs, with an estimated mean flow of approximately 100 cfs, flow into the Green River at river level, and two (Turnhole and one unnamed) rise from the river bottom (Watson, 1966).

The underground drainage network is an important tributary to the Green River as well as a major transportation system for sediment.

The amount of vertical flow (water running down joints and vertical shafts) increases after heavy rains and during wet seasons. Since the flow paths for this water are relatively open to the surface, flow within the cave can increase very rapidly. These ephemeral streams are tributary to perennial streams, which are fed by the constant inseep of subsurface water. The underground streams of the Flint Ridge Cave System are probably tributary to a much larger underground master trunk stream, which flows perenially at or just below present regional base level.

Area Studied.

The part of the cave studied is called Columbian Avenue (see map in pocket). It is essentially an elliptical tube, approximately 12 feet high and 20 feet wide. The passage maintains its dimensions consistantly throughout its length of 2,600 feet.

Entrance to the passage is gained via Pohl Avenue through an area of large breakdown blocks about 500 feet in from Austin Entrance (see Fig. 2 in back of folder). The lower end of Columbian Avenue merges with Eyeless Fish Trail. There are only a few side leads from Columbian Ave. and these are shown in Figs. 1 and 2.

The top 300 feet of the passage is fairly free of sediment. The floor is bedrock or breakdown blocks covered with a layer of clay and fine silt 3-4 cm. thick. The passage is 8-15 feet high for about 1,000 feet. Sediments vary from 1 to 5 feet thick in this area and in many places there is a bedrock floor in the center of the passage covered with small breakdown blocks and 1 foot of sediment. Sediment "shelves" on the sides of Columbian Avenue in this area vary from 3 to 6 feet high and 2 to 10 feet wide.

The next 1,000 feet of passage is a crawlway that ranges from 2-4 feet high and averages about 15 feet wide. Cores taken from this area indicate that the bedrock floor is 5 to 9 feet below the surface of the sediments in most places.

The last 600 feet is divided into two sections: 1) a 300-foot section with and 8-10 foot high ceiling and sediment shelves; 2) a 300-foot interval with ceilings 2-3 feet high and assumed to contain 8-12 feet of sediment. (see Figs. 1-3).

Sampling Mehtods.

The first study of sediments in Columbian Avenue was conducted in November, 1967. Four samples of the surface layer were taken in the upper 600 feet of the passage. Several samples of soil and residual clay material in outcrops on the Sinkhole Plain were also collected.

An x-ray diffraction pattern was obtained for each of the samples at Ohio State through use of a G.E. diffractometer housed in Mendenhall Laboratory. The samples were dispersed, using $NaCO_3$ as a dispersing agent, and allowed to settle for two hours before pipetting off a sample.

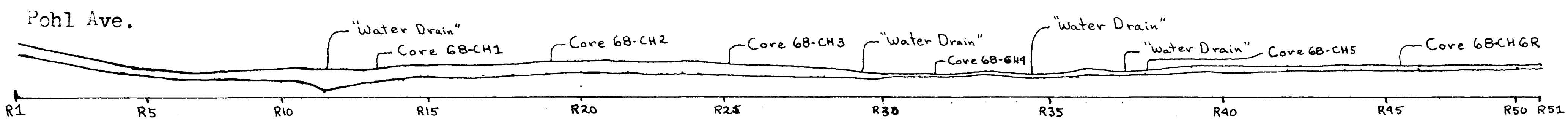
The purpose of this examination was to find out if there was a significant difference between the sediments on the floor of Columbian Avenue and the soil on the Sinkhole Plain. The patterns showed no differences in mineral content. Quartz, kaolinite, and illite were prominent in all samples.

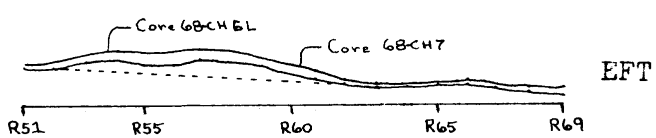
In December, 1967, a coring method was attempted with equipment loaned to us by Dr. P.A. Colinveaux of the Faculty of Population and Environmental Biology of The Ohio State University. This equipment consisted of 1.0-meter and 0.5-meter aluminum tubes, to which could be attached an iron cutting bit. A plunger could be placed inside the tube and be pulled up as the tube was driven into the sediments. The purpose of the plunger was to overcome the suction of the sediment and remove a clean core from the hole.

Eighty pounds of equipment were carried from the base camp 1,000 feet into the cave. It was rapidly discovered that this method of sampling was not feasible due to the high water content of the sediments and the number of sand layers encountered in the cores. Only half of a 1.0-meter core could be recovered effectively.

FIGURE 3

Cross section of Columbian Avenue from Pohl Avenue to Eyeless fish Trail. Base line is 7.00' level of Green River at Mammoth Cave ferry. "Water drain" and core locations as indicated (see also Fig. 1). Dotted line indicates level of floor in tube connecting stations R52 and R62. Lower line is lowest floor elevation at each station; upper line indicates ceiling level.

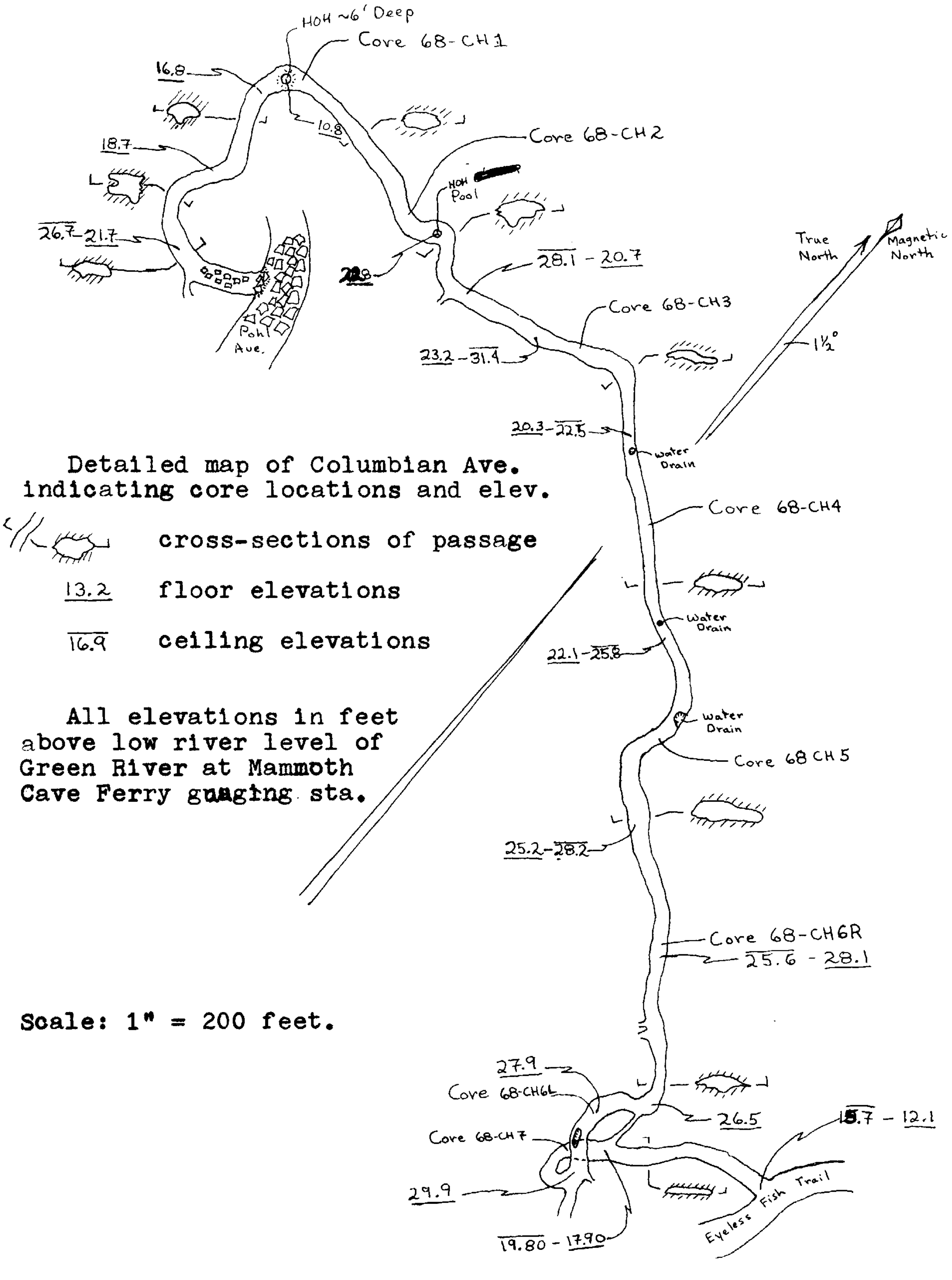




Vertical Scale: 1"= 100'

Horizontal Scale: 1"= 200'

FIGURE 1



Detailed map of Columbian Ave. indicating core locations and elev.

cross-sections of passage

13.2 floor elevations

16.9 ceiling elevations

All elevations in feet above low river level of Green River at Mammoth Cave Ferry guaging sta.

Scale: 1" = 200 feet.

The bedding was greatly disturbed when the core was removed from the tube. This method of sampling was given up as useless for the type of sediments involved.

In February, 1968, a successful coring technique was put into operation. This technique uses 10-foot lengths of Wiremold 3000, a steel, U-shaped trough 2 inches wide and 1 inch deep. A hole, approximately 4 feet long and 2 feet wide, was dug at each sample site. The hole was extended down to the bedrock floor. One wall of the pit was cleaned off and the trough was tamped into that wall. A wire lowered over the top of the trough served to cut the sediment and leave an undisturbed vertical core in the metal trough.

The cores were kept in the troughs and wrapped in plastic sheeting for transportation out of the cave to The Ohio State University. Cores 68-CH1 through 68-CH4 were collected on the February trip. These locations are plotted on the map of the passage (see Fig. 1). A traverse consisting of 50 foot intervals was also run down the passage to locate future sample sites and find the general length of Columbian Avenue.

A trip in March, 1968, was unproductive as far as core collection was concerned, but interesting observations were made. The Green River was flooding and the water level at Mammoth Cave Ferry was 27.5 feet above low-water level. Water was backed up in Columbian Avenue to within 30 feet of Pohl Ave. Later examination showed that this flood had deposited an extremely thin layer of clay on the passage floor.

In April, 1968, cores 68-CH5 through 68-CH7 were collected by the method described above. These core locations are also shown in Figure 1. Several additional interesting observations were made at this time. In the bottom layers of cores 68-CH5, 68CH6R, and

68-CH6L, water flow was encountered and the holes filled rapidly with water upon reaching a level 1 foot above the bedrock floor. Direction and rate of flow could not be determined.

A pit located at the intersection of Eyeless Fish Trail and Columbian Avenue had to be abandoned at the two-foot level due to excessive water flowage into the hole. There are at least 10 feet of sediment at this location and water apparently flows in the lower 8 feet under the surface into Eyeless Fish Trail.

In the late Spring of 1968 a latex-peel method of obtaining a record of core layers was attempted. The latex failed to penetrate the clay and silt layers and the method was unsuccessful. The cores were stored in Orton Hall for the summer, wrapped in plastic to reduce loss of moisture by evaporation. On return to school in September, 1968, we discovered that core 68-CH1 was not well wrapped and had dried out, ruining it for further study.

September through November, 1968, were spent describing and analyzing the cores brought back from Kentucky. Cores 68-CH2 and 68-CH3 were divided into 4-inch intervals and sampled in the center of each interval in hopes of finding a significant vertical size distribution in the cores. These two cores were not described before sampling and were wasted in that respect. The results of these samples were recorded and are illustrated on pages 62 to 95 of the Appendix.

The sampling methods used on cores 68-CH5 through 68CH7 were as follows: 1) a generalized description of the core, including bedding patterns, general units, color and size fractions; 2) sampling of significant units (including in each case a sample of the top layers) accomplished by removing a sample approximately 3 cm.

high, 1 inch deep and 2 inches wide, averaging 55 grams dry weight; 3) size analysis of the sample, including: a) dispersion in 950 ml DDW and 50 ml of 36.56 g/l $NaCO_3$ solution; b) wet seiving through 230 mesh (0.0625mm) screens; c) separation of the fraction greater than 0.0625mm to be dried and screened through 10, 18, 35, 60, 120, and 230 mesh screens; d) removing the fraction less than 0.0625mm and, using the hydrometer (with appropriate temperature corrections), taking readings of colloidal suspensions (at 1 min. 55sec., 7 min., 34 min., 150 min., and 180 min.) in grams/liter; 4) determining the weight % of each size fraction and graphing it as a cumulative weight % on 4 x 10 semi-log graph paper; 5) describing the fraction greater than 0.0625mm by inspection under the binocular microscope; 6) taking x-ray diffraction patterns of the minerals in several selected colored units using the less than 0.0039mm size fraction pipetted off at 150 min. in the hydrometer runs.

The results of these samples are shown on pages 1 through 61 of the Appendix.

In November, 1968, a horizontal survey was run in Columbian Avenue to obtain a map of the area and get reasonable cross sections of the passage. At the same time a level survey was run in the passage from Eyeless Fish Trail to Pohl Avenue to determine the gradient of the floor and ceiling of the passage. This information is illustrated in Figure 1.

An interesting note on the amount of work required to get the cores necessary for this project is that approximately 56 tons of dirt were removed in and out of the coring holes and approximately 250 man-hours were spent underground during the coring trips. The aid of the Cave Research Foundation and the people involved in it is again acknowledged and appreciated.

Conclusions.

Literature on cave sediments in the Mammoth Cave region is very limited. Collier and Flint (1964) concluded on the basis of measurements between October 1959 and June 1962 that sedimentation in Mammoth Cave is closely related to flooding of the nearby Green River. They argue that the Green River, which is hydrologically connected to Mammoth Cave, is the chief source of sediment and floodwater to the cave. Watson (1966) disagrees with this in implication and in detail. He argues that the cave systems are the chief local sources of sediment and floodwater to the Green River. Sediments are derived from the Sinkhole Plain and surrounding areas and carried into the underground drainage network through joints or vertical shafts. Davies and Chao (1959) find that most of the sediments in the big trunk drain conduits of Mammoth Cave consist of gravel (mostly rounded quartz pebbles from the basal Caseyville Formation), sand and silt. Clay is uncommon.

As shown in the graphs (size versus cumulative percentage) and in the columnar sections, the sediments become progressively coarser towards the bottom. Coarse sediments are regularly found at the bottom. Collier and Flint (1959), who propose a simple backflooding mechanism of the Green River as a means of deposition of the sediments (mainly silt and clay), cannot justify the presence of a large amount of sand and gravel. The deposition of the sediments may be in two parts. The clay and silt at the top of the sections may be deposited and reworked by repeated rise and fall of flood waters. There may exist a situation in which sediment is being added to the cave at the top of the floodwater zone while a larger volume of sediment is being transported through and out of the cave at the base of the main water-carrying conduits. The sands and gravels may have been washed in from the Sinkhole Plain above and deposited earlier in the history of the deposition.

Several observations made in the field lead to fairly obvious and important conclusions concerning sedimentation in Columbian Avenue. First, after the flood in March 1968, a thin layer of clay was deposited on the floor of the passage. Since the Green River floods at least once a year, it is important to note that sedimentation rates in Columbian Ave. are extremely low at this time. There is no permanent surface stream in the passage at present, so we conclude that active sedimentation is a result of clay and silt-sized particles being re-worked or brought in by floodwaters of the Green River.

The major outlet and inlet of floodwaters is Pike Spring (see Fig. 2 in back pocket) which is separated at least 3,000 feet horizontally and 12 feet vertically from the entrance to Columbian Avenue. It is difficult to imagine floodwaters maintaining their velocity and turbulence through 3,000 feet of twisting and turning cave passage long enough to carry particles any larger than silt.

Other interesting features of Columbian Ave. are the water drains, which are located in Fig. 1. These drains appear to be the major drains for floodwaters leaving the passage. They are suspected to go down to the bedrock floor where they discharge their water into a relatively permeable gravel layer at the base of the section (see columnar sections in Appendix). A large base flow was noticed in this gravel layer during collection of the samples. It seems likely that a small amount of sediment may move through and out of the cave in the permeable layer at the base of the main sediment body. Evidence of this is the large number of sand units completely free of silt and clay in the lower part of the cores sampled (see Appendix).

A history of Columbian Avenue might proceed as follows: 1) active solution of the limestone cavern at or near the water table and assumption by the passage of the elliptical shape prevalent in this system (Deike,1967); 2) downcutting of the Green River, thus lowering base level, and consequent deposition of residual material from the surface sinkhole plain in the passage as it acts as a major drain for the system; 3) pirating of the major drainage by Eyeless Fish Trail and abandonment of Columbian Ave. as an active stream-depositional site; 4) as base level lowers, Columbian Ave. gets less and less water from the sinkhole areas and becomes a site of clay and silt deposition from floodwaters; 5) development of "sinks" in the passage to allow water to flow in the more permeable lower layers rather than on the inpermeable silt and clay of the surface; 6) overall loss of sediment (especially fines) as a result of subsurface flow; 7) further lowering of base level will eventually bring Columbian Ave. above floodwater level making it stagnant as far as sedimentation is concerned.

Evidence for the above is indicated in the cores listed in the Appendix. A size change from coarse to fine can be seen in every core from top to bottom. Turner Avenue, another passage shaped much like Columbian Avenue, is known to contain sediments much like Columbian Avenue, but is located at least 80 feet above high water during flood stage of the Green River (W.B. White, personal communication).

Our data and descriptions are too tenuous at the moment to attempt to resolve the arguments involved. Measurements of grain-size distributions as a function of distance from the Green River could provide some valuable evidence. These measurements made in apparently equivalent horizons, seem feasible with some very careful field work. Cores must be taken at intervals of less than 100 feet apart. This is necessary because of the rapid facies changes shown in the cores taken in this study. Rate and direction of flow and the amount of suspended colloids in subsurface waters should be measured for each coring hole dug. Turbulence and velocity of floodwaters entering the cave should be measured to give a clearer idea of what size of particles that could be transported by them. A more detailed study of the sediments in situ might lead to a better correlation between cores than made in this study.

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